Operation Experience of KCCH Cyclotron for 10 years and Prospect of Cyclotron in Korea

J.S.Chai Y.S.Kim D.H.Lee J.D.Lee
Cyclotron Application Laboratory, Korea Cancer Center Hospital, KAERI,
Seoul 139-240, South Korea

S.Y.Yoo
Department of Therapeutic Radiology, Korea Cancer Center Hospital, KAERI,
Seoul 139-240, South Korea

The first cyclotron installed at Korea Cancer Center Hospital, Korea Atomic Energy Research Institute has been utilized for basic medical researches and treatment of cancer patients in addition to production of radioisotopes since 1986. KCCH c-cyclotron continues to be used for routine neutron therapy and over 410 patients have been treated over the past 9 years. We have produced ^{67}Ga, ^{201}Tl,^{123}I, ^{111}In for medical use which are delivered to the hospitals in Korea. Now there are 3 cyclotrons included KCCH cyclotron in Korea. Some hospitals are considering importance of cyclotron for PET. In this paper we described the operation status of KCCH cyclotron and also mentioned past, present, and future for the cyclotrons in Korea

1 INTRODUCTION

In the early 1980's the interests in neutron therapy and the number of centers applying this mode of treatment, had grown considerably. After 4 years of planning, equipment acquisition, facility construction and beam testing, the KCCH cyclotron facility could be extracted the first beam in January 1986. The KCCH cyclotron at Korea Cancer Center Hospital, Korea Atomic Energy Research Institute in Seoul is based on a Scanditronix built MC50 cyclotron with an isocentric neutron therapy gantry and 2 solid target and 1 gas target system for radioisotopes. Neutron therapy has been in routine operation since 1986. The original mission of this system is to treat patients on a routine basis, concentrating on tumor systems. Even if cancer therapy with fast neutrons continues to exhibit favorable results for several selected disease sites, cancer patients to be treated by neutron therapy have been decreased after 1992[1]. There are 3 target station which are consist of 2 solid targets and 1 gas target. Originally PET was planned to be installed at the same time with cyclotron installation, but that plan was changed, PET scanner will be installed early next year[2]. Since 1987 ^{67}Ga, ^{201}Tl,^{123}I, ^{111}In have been produced and delivered 6 general hospitals in Korea. We produced radioisotopes totally 8 Ci in 1994[3].

2 Facility Description of KCCH Cyclotron

The KCCH cyclotron is variable energy isochronous cyclotron for acceleration of light particles. The cyclotron is designed to deliver high quality external beams of easily controlled energy and intensity for use in physics, medicine, and biology. Although primarily intended for acceleration of protons, deuterons, and helium ions, it can be also produced beams of heavier elements like carbon, nitrogen, and oxygen. Maximum energies are for protons 52 MeV, deuterons 26 MeV, Helium-3 66 MeV, and Helium-4 50.5 MeV The magnet of KCCH cyclotron is made of friged steel and has a total weight of 93 tons. It is apart from a scale factor and an increase of the sector spiral angle to 55 degrees. It has three spiral shaped sectors. There are 3 kinds of coils, main coil, ten concentric trim coil, and four sets of harmonic coils. The main coils are directly water cooled and wound from glass fiber insulated, hollow copper conductors cast in epoxy. The harmonic coils are electrically connected in such a way that the amplitude and azimuth of the first harmonic disturbance can be set independently. The RF system is of driven type and comprises two identical 90 degree acceleration structures with associated power amplifiers located on opposite sides of the cyclotron magnets. Both systems are mastered by a common frequency synthesizer. Each of the two RF cavities consist of a quarter wave length transmission line stem capacitively loaded by the 90 degree dee at the high voltage end. The interdee phase, which can be set at 180 or 0 degrees is also feedback controlled. The RF system is fully automated to simplify operation. All important parameters in the RF systems can be monitored from local panels. The ion source is PIG discharge type with the lower cathode directly heated by a filament. The source is inserted vertically from below through an air lock, which enables both anode, cathodes or extraction slits to be inspected or exchanged without breaking the machine vacuum. The beam is extracted from the cyclotron at a radius of about 57 cm by means of the orbit processional method. A first harmonic perturbation created by the extraction coils is used to excite a coherent oscillation of the beam when it passes the resonance $\nu_r = 1$ located close to the edge of the magnet. when the beam has reached $\nu_r \simeq 0.85$ the procession gives a sufficient turn separation to bring it into the extraction channels. The first extraction channel is electrostatic and has an azimuthal extension of 45 degrees. The second extraction channel is electromagnetic and produces a field reduction of 1.4 kG over 35 degrees of azimuth.

Table 1. Perfomance of the KCCH Cyclotron

	Energy (MeV)	Internal Beam Current	External Beam Current
Proton	18 - 52	100 μA	60 μA
Deutron	9 - 25.5	100 μA	60 μA
Helium-3	24 - 67	50 μA	35 μA
Helium-4	18 - 50.5	50 μA	35 μA

3 KCCH Cyclotron operations

The beam transport system consists of one switching magnets for deflections from +52 degrees to -52 degrees and five beam pipe connections. At present four of the connections are target station line for radioisotope production, neutron gantry line, beam analysis line and nuclear physics line in operation. In the target station, there is another switching magnet for gas target and solid target. The acceptance of the beam guiding system is sufficient to achieve a transparency over 90 mrad in the horizontal direction. The beam cross sections on the neutron target and the radioisotope target are less than 4x4 mm^2 and 20x20 mm^2, respectively. In the case of radioisotope production, the beam energy in the range of 35-50 MeV is obtained by changing of acceleration frequency. I-123 is produced at 50 MeV, Tl-201, Ga-67, In-111, and Cr-51 at 35 MeV Under normal operating conditions, Monday is used for preventive maintenance, Tuesday, Wednesday and Thursday for neutron therapy, and Tuesday early morning, Friday and Saturday for radioisotope productions. The accumulated beam delivery in 1994 was 44.032 mA-hour and the weekly average beam delivery was 0.815 mA-hour/week.

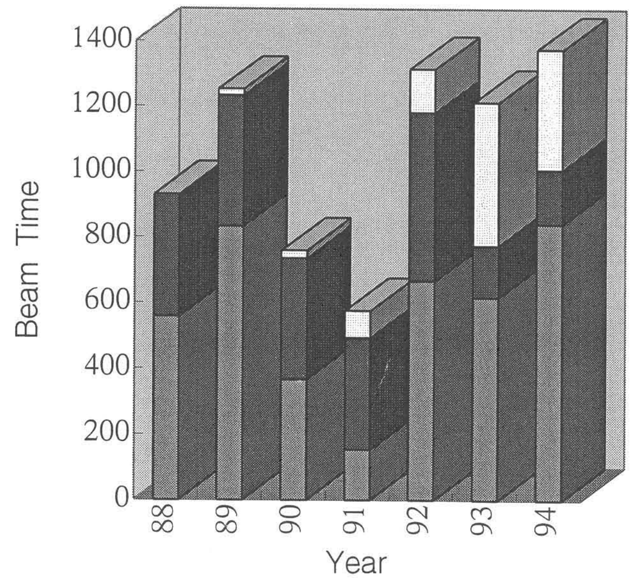

Figure 1: Total beam time for each year, where white, black and gray are Research, neutron therapy and RI production

3.1 Neutron Therapy

The treatment room is equipped with an isocentric gantry with 360 degree rotational capability. This gantry system was built by Elven precision, England, a subcontractor of Scanditronix. The gantry head contains a 10 mm thickness Be target in which protons lose 50 energy is deposited in the copper backing plate. There are the beam flattening filters, dual dosimetry system, wedge filter system to produce asymmetric dose distributions and the beam defining lamp in the head of gantry. The head carries a neutron collimator of book-end type which can be rotated around the beam axis. In order to make the 360 degrees rotation of the gantry possibly, a 3 m-depth pit is prepared to take up the head in its down position. This pit is covered by moving floor. The standard pa-

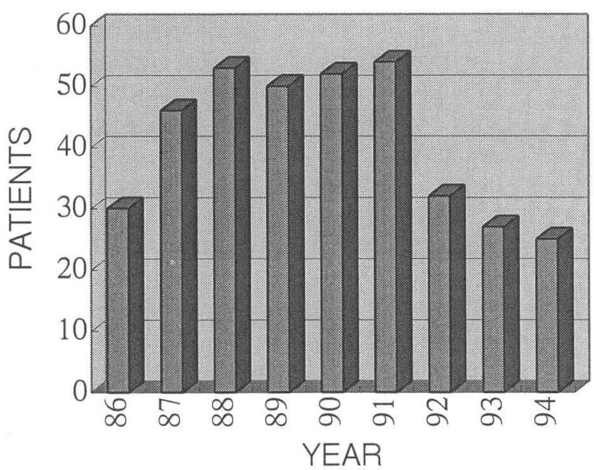

Figure 2: Patients number of neutron theraphy

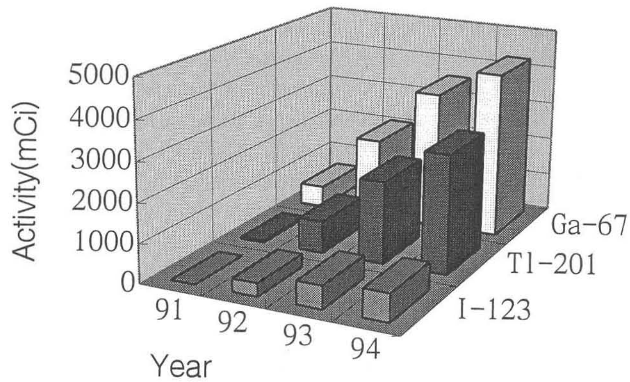

Figure 3: Distribution of RI in Korea by KCCH

tient treatment consists of 12 treatment sessions splitted over 4 weeks. Within one session a patient is irradiated from one to four different directions with different collimator set-up. On the average the patients are treated with two fields. A two-field treatment takes on the average 30 minutes ; about 20 minutes for set up and a total beam-on time of eight of twelve minutes depending on the available beam intensity and the prescribed dose[4].. From November 1986 to September 1995 we have treated 410 patients by neutron therapy. As soon as finishing of neutron gantry installation, we had many patients, but we could not treat all of them because of frequent troubleshootings at cyclotron and neutron gantry. After 1992 many people have been doubtful of treatment results for all kinds of cancer. But cancer therapy with fast neutrons continues to exhibit favorable results for several selected disease sites.

3.2 Radioisotope production

The target system for radioisotope production contains two solid target stations including the target transfer system and one gas target station with four movable target chambers. The solid target station consists of a vacuum chamber with one gate valve for beam exit and one for the carrier module port. A remotely controlled external target transfer system called as a Telelift system automatically carries a target from a loading station to a irradiation chamber. After irradiation the target will be carried back to the loading station. For irradiation of gases, the gas target is equipped, with a water-cooled energy degrader made of aluminium. The aluminium degraders in front of the target reduce the beam energy to 11-18 MeV region best suited for the production of the PET radioisotopes. An aluminium gasket is used to seal between the foil and the target body. PET scanner at KCCH will be installed early next year. Radionuclides routinely produced for medical use are Ga-67, Tl-201, I-123, and In-111. In order to increase the production yield, the proton beam of 35 MeV and 50 MeV are used for radioisotope production. In 1994 we produced four Ci of radioisotope for medical use. Most of them were distributed to hospitals in Korea. Now we are required the more production of Tl-201 and I-123. In the case of I-123 many medical doctors in nuclear medicine want to use it instead of I-131. So the market of I-123 will be fine in Korea.

3.3 Maintenance

The maintenance can be grouped into two categories. The first preventive maintenance done in the normal planned maintenance for expecting failures of cyclotron and upgrading the systems. Every Monday we have the preventive maintenance whose contents are general check and every system check. The second is unscheduled ones included repairs. Repairs should be done in short time without delay of scheduled operation. We have to prepare the spare parts for exchanging the parts. In the case of electronics we exchange the boards for the troubleshooting parts. Most of troubleshooting parts could be arrange by statistics of ten years experiences. We made a data base for experienced solution of troubleshooting. Over 40 caused by chiller system troubleshooting. New chiller system was changed in November 1994. After changing of that system cyclotron operation rate is 100 failure of low voltage power supplies. The power supplies failed by overtemperature problem were added cooling fan. After finishing installation of KCCH cyclotron beam efficiency (I_{FC1} / I_R=40) had been less 55 positionable with up and down, anode slit size to be 2 mm x 6 mm, cathode of ion source to be 8 ,

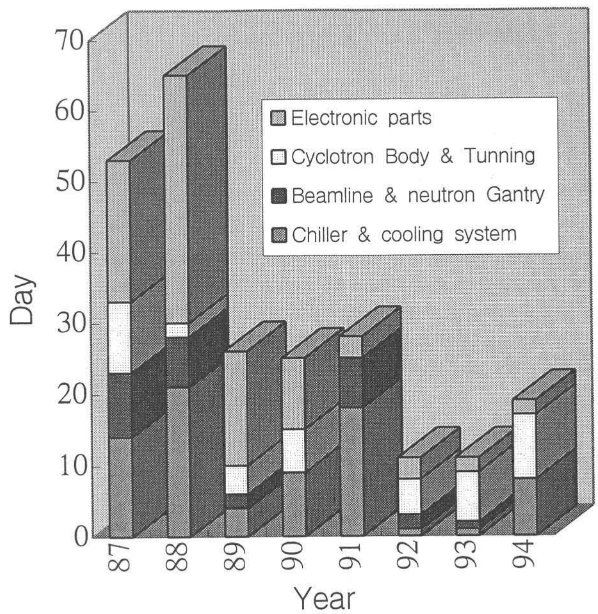

Figure 4: Failure days and parts

and changing the power supplies of number nine and ten concentric trim coils. Now we can get beam efficiency over 60 of the parts.

4 Status and Prospect of Cyclotron in Korea

Activities in the field of accelerator science have been well behind compared with those advanced countries. Economic states were extremely difficult to promote advanced science and technology from 1950's to 1970's. But in 1959 some physicists made the first cyclotron which was classical cyclotron extracted proton beam 1 MeV, 10 nA at Seoul National University. From 1980's advanced medical instruments for cancer treatment and diagnosis have been required according to economic growth. In 1982 KCCH, Korea Atomic Energy Research Institute made a contract for installation of cyclotron and neutron gantry with Scanditronix, Sweden. After that KCCH cyclotron was only cyclotron in Korea till 1993. In 1993 Seoul National University Hospital and Samsung Medical Center determined to import the PET scanner and baby cyclotron. Now four hospitals have the plan to import PET scanner and cyclotron and six hospitals are considering to import them. KCCH is considering to install of new bigger cyclotron for proton therapy and smaller cyclotron for radioisotope production exclusively. Korea Institute of Science and Technology announced to installation of proton synchrotron for proton therapy in 1995. Now many Korean people feel importance of the basic science and nuclear medical research for the cancer treatment. Korean government and science foundations are concern about the accelerators and their applications after the completion of Pohang Light Source and 2 GeV linear accelerator.

5 Conclusion

KCCH cyclotron at Korea Cancer Center Hospital, Korea Atomic Energy Research Institute in Seoul has now been in successful operation from 1992. It is used for routine fast neutron therapy, production of radioisotopes for medical use and basic research. New medical applications, in particular proton therapy may play a role in the future at KCCH.

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